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APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A
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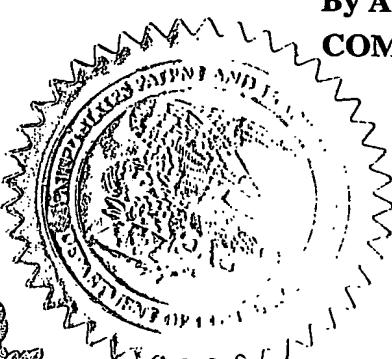
APPLICATION NUMBER: 10/408,136

FILING DATE: April 07, 2003

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T. LAWRENCE

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PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

04/10/2003 SDIRETAL 00000009 10408136

01 FC:1001 750.00 DP
02 FC:1202 54.00 DP

06/06/2003 MNNGUYEN 00000007 220493 10408136

01 FC:1202 162.00 CH
02 FC:1203 280.00 CH

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(5/87)

11042 U.S. PTO
04/07/03

04-08-03

10408136 44706

PTO/SB/05 (03-01)

Approved for use through 10/31/2002. OMB 0651-0032

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	SHP-PT075
First Inventor	Anthony John Barnes
Title	METHOD OF FORMING AND BLANK THEREFOR
Express Mail Label No.	EV 356347576 US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. Fee Transmittal Form (e.g., PTO/SB/17)
(Submit an original and a duplicate for fee processing)
2. Applicant claims small entity status.
See 37 CFR 1.27.
3. Specification [Total Pages **18**]
(preferred arrangement set forth below)
 - Descriptive title of the invention
 - Cross Reference to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to sequence listing, a table, or a computer program listing appendix
 - Background of the Invention
 - Brief Summary of the Invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
4. Drawing(s) (35 U.S.C. 113) [Total Sheets **3**]
5. Oath or Declaration [Total Pages **1**]
 - a. Newly executed (original or copy)
 - b. Copy from a prior application (37 CFR 1.63 (d))
(for continuation/divisional with Box 18 completed)
 - i. **DELETION OF INVENTOR(S)**
Signed statement attached deleting inventor(s)
named in the prior application, see 37 CFR
1.63(d)(2) and 1.33(b).
6. Application Data Sheet. See 37 CFR 1.76

ADDRESS TO: Commissioner for Patents
Box Patent Application
Washington, DC 20231

7. CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
 - a. Computer Readable Form (CRF)
 - b. Specification Sequence Listing on:
 - i. CD-ROM or CD-R (2 copies); or
 - ii. paper
 - c. Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. Assignment Papers (cover sheet & document(s))
10. 37 CFR 3.73(b) Statement Power of (when there is an assignee) Attorney
11. English Translation Document (if applicable)
12. Information Disclosure Statement (IDS)/PTO-1449 Copies of IDS Citations
13. Preliminary Amendment
14. Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
15. Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. Other: P.T.O.-2038

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

Continuation Divisional Continuation-in-part (CIP)

of prior application No. _____

Prior application Information: Examiner _____

Group Art Unit: _____

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

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Address			
City	State	Zip Code	
Country	Telephone	Fax	

Name (Print/Type) **Ruy M. Garcia-Zamor** Registration No. (Attorney/Agent) **44,117**

Signature  Date April 7, 2003

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10408136 104070

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FEE TRANSMITTAL for FY 2003

Patent fees are subject to annual revision.

 Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT (\$ 804.00)

Complete if Known

Application Number	Not Yet Known
Filing Date	Not Yet Known
First Named Inventor	Anthony John Barnes
Examiner Name	Not Yet Known
Art Unit	Not Yet Known
Attorney Docket No.	SHP-PT075

METHOD OF PAYMENT (check all that apply)

 Check Credit card Money Order Other None
 Deposit Account:

Deposit Account Number	22-0493
Deposit Account Name	Volpe and Koenig, P.C.

The Commissioner is authorized to: (check all that apply)

 Charge fee(s) indicated below Credit any overpayments
 Charge any additional fee(s) during the pendency of this application
 Charge fee(s) indicated below, except for the filing fee to the above-identified deposit account.

FEE CALCULATION

1. BASIC FILING FEE

Large Entity	Fee Code (\$)	Fee	Small Entity	Fee Code (\$)	Fee	Fee Description	Fee Paid
1001	750	2001	375			Utility filing fee	750.00
1002	330	2002	165			Design filing fee	
1003	520	2003	260			Plant filing fee	
1004	750	2004	375			Reissue filing fee	
1005	160	2005	80			Provisional filing fee	
SUBTOTAL (1)		(\$ 750.00)					

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

Total Claims	23	- 20 =	3	Fee from below	Fee Paid
Independent Claims	2	- 3 =	0	X	0
Multiple Dependent					

Large Entity	Small Entity	Fee Description
1202	18	2202 9 Claims in excess of 20
1201	84	2201 42 Independent claims in excess of 3
1203	280	2203 140 Multiple dependent claim, if not paid
1204	84	2204 42 ** Reissue independent claims over original patent
1205	18	2205 9 ** Reissue claims in excess of 20 and over original patent
SUBTOTAL (2)		(\$ 54.00)

** or number previously paid, if greater. For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity	Small Entity	Fee Description	Fee Paid
1051	130	2051 65 Surcharge - late filing fee or oath	
1052	50	2052 25 Surcharge - late provisional filing fee or cover sheet	
1053	130	1053 130 Non-English specification	
1812	2,520	1812 2,520 For filing a request for ex parte reexamination	
1804	920*	1804 920* Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805 1,840* Requesting publication of SIR after Examiner action	
1251	110	2251 55 Extension for reply within first month	
1252	410	2252 205 Extension for reply within second month	
1253	930	2253 465 Extension for reply within third month	
1254	1,450	2254 725 Extension for reply within fourth month	
1255	1,970	2255 985 Extension for reply within fifth month	
1401	320	2401 160 Notice of Appeal	
1402	320	2402 160 Filing a brief in support of an appeal	
1403	280	2403 140 Request for oral hearing	
1451	1,510	1451 1,510 Petition to institute a public use proceeding	
1452	110	2452 55 Petition to revive - unavoidable	
1453	1,300	2453 650 Petition to revive - unintentional	
1501	1,300	2501 650 Utility issue fee (or reissue)	
1502	470	2502 235 Design issue fee	
1503	630	2503 315 Plant issue fee	
1460	130	1460 130 Petitions to the Commissioner	
1807	50	1807 50 Processing fee under 37 CFR 1.17(q)	
1806	180	1806 180 Submission of Information Disclosure Stmt	
8021	40	8021 40 Recording each patent assignment per property (times number of properties)	
1809	750	2809 375 Filing a submission after final rejection (37 CFR 1.129(e))	
1810	750	2810 375 For each additional invention to be examined (37 CFR 1.129(b))	
1801	750	2801 375 Request for Continued Examination (RCE)	
1802	900	1802 900 Request for expedited examination of a design application	
Other fee (specify)			
*Reduced by Basic Filing Fee Paid		SUBTOTAL (3) (\$ 0)	

SUBMITTED BY				(Complete if applicable)	
Name (Print/Type)	Ruy M. Garcia-Zamor	Registration No.	44,117	Telephone	215-568-6400
Signature				Date	April 7, 2003

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Express Mail Label No. EV 356347576 US

APPLICATION DATA SHEET
UNDER 37 CFR §1.76

(1) Inventor Information

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Name Line Two::	Volpe and Koenig, P.C.
Telephone No.::	215-568-6400

(3) Application Information

Title Line One::	METHOD OF FORMING AND BLANK
Title Line Two::	THEREFOR
Total Drawing Sheets::	3
Drawing Type::	Formal
Application Type::	Utility
Docket No.::	SHP-PT075

(5) Representative Information

Representative Customer No.: 3624

SHP-PT075

Express Mail Label No. EV 356347576 US

[0001] **METHOD OF FORMING AND BLANK THEREFOR**

[0002] This invention relates to a method of material forming to produce shaped parts, and to a blank for use in such forming. The invention is particularly directed to the superplastic forming (SPF) process utilising certain materials, primarily metallic, which exhibit superplastic properties.

[0003] Superplasticity can be defined in various different ways, but generally it is. A property exhibited by certain materials whereby they are able, at an appropriate temperature and strain rate, typically in the range 10^{-3} to 10^{-4} , to undergo plastic deformation to very large (eg 200% or more) elongations under tension without rupture. High strain rate superplasticity may be defined as a minimum strain rate of 10^{-2} S^{-1} and is typically found in materials produced by Equal Channel Angular Pressing (ECAP) or friction stir processing (FSP). Materials which possess superplastic properties may be formed, using processes such as SPF, into complex 3D shapes such as are needed in the aerospace and automotive industries.

[0004] Several materials exhibit superplastic properties, but only a relatively small number find commercial applications. These include certain alloys of aluminium, titanium and nickel. Various methods can be used to achieve the fine grain microstructure which is necessary for materials to exhibit superplasticity. Unfortunately these methods usually involve quite complex and expensive processing to convert a base material, which does not possess superplastic properties at all or only to a small extent, into one which does possess the required superplastic properties. For example, US patent application No.2002/0079351 describes a technique in which superplastic properties are generated locally in a parent metal using friction stir welding (FSW). The blank thus created can thence be deformed to create a desired 3D article by a forming process such as forging, rolling, drawing, bending, extruding, gas forming, punching or stamping. That part of the blank which has been

SHP-PT075

rendered superplastic by the FSW is sufficiently ductile to deform to the required shape whereas the remainder of the blank is not.

[0005] Friction stir welding is a relatively new technique. The basic process is described, for example, in WO93/10935 and is typically used to join two workpieces. The process involves plunging a rotating or reciprocating probe into the workpiece to be joined, and moving the probe along the line of the join. The heat generated by the frictional engagement of the probe with the workpieces generates an area of plasticised material which, after passage of the probe, joins across the join line to weld the workpieces together.

[0006] In the present invention, we seek to achieve a blank which is functionally similar to that obtained in the process described in the above-mentioned US patent application No. 2002/0079351 in that it comprises a limited area within the parent metal which has superplastic properties and which thus, during a subsequent forming process, will readily deform to produce the required shape, leaving the remaining material either not deformed at all, or deformed only to a limited extent within its plastic capabilities. The technique of the present invention leads, however, to a number of advantages over the prior-art process, which advantages will become apparent in the following description.

[0007] According to a first aspect of the invention there is provided a method of preparing a blank for superplastic forming, said method comprising the steps of joining an insert to a parent body by means of friction stir welding, at least one of the parent body and the insert being made of a material which has superplastic properties.

[0008] Any suitable method of forming can be used, such as those listed above, but the preferred method is superplastic forming at elevated temperature with pressurised fluid, as will be described in more detail below.

[0009] In accordance with a second aspect of the invention there is provided a blank for use in a superplastic forming process in which a limited region or regions of the blank are required to deform to a greater extent than the

SHP-PT075

remainder, said blank comprising a parent body and an insert joined thereto by means of friction stir welding, at least one of the parent body and the insert being made of a material which has superplastic properties, and wherein that part of the blank which has said superplastic properties is positioned so as to correspond to a respective limited region.

[0010] The use of the terms "parent body" and "insert" are not intended to simply any particular size relationship between the two, but are used simply to enable the two parts to be readily distinguished. It will, however, often be the case that the part of the blank that is superplastic will be the smaller in size since investigation has shown that, in many cases, it is only a relatively small proportion of a blank that is subjected to deformation, during the forming process, of sufficient magnitude to warrant the need for a superplastic material. Thus, fabricating the whole blank of superplastic material is often unnecessary and, since such materials are more expensive to produce, costs can be saved by using as little as possible of the superplastic material. However, we do not wish to exclude the possibility that the remainder of the blank is also of superplastic material and, indeed, the degree of superplasticity of the parent body, whilst normally different to that of the insert, may in certain circumstances be of a similar level to or equal to that of the insert.

[0011] In the preferred embodiment it is the insert that is formed of superplastic material, and the parent body is formed from a material which is either not superplastic at all, or is superplastic to a lesser extent. For simplicity of description, this arrangement will be assumed hereafter. Thus, during the forming process, there are two possibilities:-

- 1) The parent body remains undeformed during the forming process, deformation only occurring within the insert;
- 2) Both the parent body and the insert are deformed during the forming process, but the insert is positioned in that region which requires an amount of deformation sufficient to warrant the use of a superplastic material, the remaining parts being deformed to a lesser extent than this.

SHP-PT075

[0012] The blank may be formed of multiple inserts, each frequency stir welded to the parent body. Some or all of these inserts may be made out of superplastic material. In addition, the or each insert may further be provided with means whereby it may perform a mechanical function, for example stiffening or providing a threaded bore for a fastening in the finished part.

[0013] The or each insert may be positioned in relation to the parent body in various different ways. For example an insert may simply abut one edge of the parent body and be joined along the abutting edge. Alternatively, the parent body may be cut out to receive the insert, either by way of slot opening into an edge of the parent body, or by way of a closed cut-out in the parent body. In a further alternative, the insert may overlie the parent body and be joined thereto, thus forming a two-layered composite structure in the area of the insert. Such an insert may more properly perhaps be referred to as a patch, since it is not "inserted" into an opening in the parent body. Thus the word "insert" as used herein should be construed with this in mind. Where a two-layered region is formed by a patch-type insert, care needs to be taken with the properties of the underlying material of the parent body; clearly the superplasticity of the two-layered structure is dictated by both layers, and if the plasticity of the parent body, at least in the region concerned, is not the same as or similar to that of the insert, then the overall superplasticity may be impaired. In a still further alternative, an insert and a patch may be used, by joining a patch in such a way as to wholly or partially overlie an existing insert thus forming, in effect, a composite insert comprising two layered parts. In practice, both parts of such a composite insert may be joined to the parent body in a single FSW operation.

[0014] A particular benefit of friction stir welding as a joining method is that it is a solid state process in which there is no melting, unlike conventional fusion welding where melting occurs. Accordingly the superplastic properties of the or each insert are not impaired during the joining process; indeed in the immediate area of the join they may be enhanced. In addition the area of superplasticity

SHP-PT075

may be extended for a short distance into the parent body (see the above-mentioned US patent application No. 2002/0079351). By contrast, fusion welding creates a cast material in the area of the join, together with heat-affected areas leading to reduced ductility.

[0015] The or each insert may or may not be the same thickness as the parent body. In one embodiment the insert is thicker than the parent body, but tapers at its edges so as to avoid a step where it joins the parent body. Such a step would be undesirable in the event that FSW is used since the FSW tool is normally waisted and thus a substantially equal thickness on each side of the join is desirable, although techniques for FSW welding of sheets presenting different thicknesses along the line of the join are now available.

[0016] One or both surfaces of the insert may be contoured to achieve particular desired properties, as will be explained in more detail hereinafter.

[0017] Making the insert thicker and/or contouring the surface of the insert is usually carried out either to compensate for local thinning of the material during forming, or for mechanical reasons such as a requirement for local stiffening, or the need to secure a fastening. It will be seen that, where thinning is a particular concern, the parent body and the insert may both have superplastic properties and moreover, the superplasticity of the insert may be little, or even no, greater than that of the parent body. Generally speaking however, as already mentioned, the superplasticity of the insert will be greater than that of the parent body.

[0018] Where there are multiple inserts, they may have different thickness, according to the particular requirement at their location; likewise some may be contoured, others not, or there may be a mixture of contouring and different thicknesses amongst the various inserts.

[0019] As well as having a higher degree of superplasticity from the parent body, the or each insert may be in a different metallurgical condition, for example may have a different temper, degree of hardening or grain size. It may

SHP-PT075

also have a different chemical composition, or may even be a different material entirely.

[0020] The preferred shape of the blank is sheet-like or plate-like, but it could be tubular, or an extrusion or casting, depending upon the circumstances. The component parts making up the blank – i.e. parent body and insert(s) will be shaped to give the required final shape to the blank. The thickness of the materials used to fabricate the blank are selected to meet the particular requirements of use. FSW has been demonstrated to work down to a thickness of about 1.2 mm and, at the upper end, pneumatic superplastic forming of plates 10 mm thick or possibly thicker still can be contemplated. Such thick plates can be readily joined by friction stir welding but for superplastic forming the material would preferably incorporate materials having a grain size of 10 microns or less, preferably 5 microns or less, which inherently have very low flow stress making, for example, pneumatic forming, a realistic possibility.

[0021] The most likely materials for the components of the blank are metallic materials such as aluminium, but plastics materials are also possible.

[0022] The time needed to form a sheet metal part by SPF is dictated by the superplastic characteristics of the starting sheet, the process conditions (temperature and applied pressure) and the degree of strain required to stretch the sheet into conformance with the mould. Superplastic deformation is achieved over a discrete strain rate range within which the material exhibits a high strain rate sensitivity. For a given alloy this superplastic strain rate range can be modified by the prevailing grain size. Within limits larger grains: slower forming, finer grains: faster forming. Additionally, finer grain size results in a lower flow stress for a given rate of forming. This knowledge has led to the development of "high strain rate" fast forming superplastic alloys. Such alloys may be of conventional composition but have been thermo-mechanically processed by processes such as "equal channel angular pressing" (ECAP) or "friction stir processing" (FSP) to yield ultra fine stable grain size, or they have

SHP-PT075

been produced by exotic processing methods such as mechanical alloying and physical vapour deposition.

[0023] These "fast forming" alloys have some common limitations. They are expensive to produce and have not, at least as yet, shown the ability to be easily scaled up to produce full size sheets. These limitations have meant that their promise of faster superplastic forming for commercial parts production has not been realised.

[0024] The present invention enables the utilisation of these "fast forming" materials as local inserts in regions of higher strains within a more cost-effective larger sheet of "regular" superplastic alloy or conventional non-superplastic material. This allows the "combination sheet" to form more quickly and for the high cost of the insert material, to have limited impact on overall cost.

[0025] In order that the invention may be better understood, several embodiments thereof will now be described by way of example only and with reference to the accompanying drawings in which:

[0026] Figures 1 to 4 are diagrammatic plan views of rectangular blanks suitable for use in the method of the present invention;

[0027] Figures 5A, B and C are views similar to those of Figure 1, showing three further configurations of blank;

[0028] Figures 6A to F illustrate the sequence of steps in a typical forming method according to the invention;

[0029] Figure 7 is a diagrammatic perspective view of the shaped part to be made using the method illustrated in Figure 6; and

[0030] Figures 8A-F are a series of sectional views for the purpose of clarifying the manner in which an insert may be joined to a parent body of sheet-like material.

[0031] Referring firstly to Figure 1, there is shown a blank 1 of rectangular

SHP-PT075

shape, and made out of sheet material. It will be understood that the size and shape of the blank will be dictated by the individual requirements and will not necessarily be as shown.

[0032] The blank has a composite structure comprising a parent body 2 and an insert 3, the latter being shown shaded. The join between the insert and the parent body 2 is made by welding, using the technique of friction stir welding. Friction stir welding is effected by passing a rotating or reciprocating tool along the joint line, and this is illustrated diagrammatically in Figure 1, with the tool being represented by the reference 4. In the case of a rotating tool, the tool 4 rotates about an axis which is vertical or near vertical to the general plane of the blank and is moved into the joint at the arrow marked IN, thence round the join line, and exits the joint at the arrow marked OUT.

[0033] As will be explained in more detail below, the blank illustrated in Figure 1 is subject to a hot forming operation to produce a 3D article of desired shape. During this operation the material of the blank will be deformed and the inherent plasticity of the material of the blank is relied upon during this deformation. However, the inherent plasticity may not be sufficient to produce complex shapes, including such features as sharp curves and corners, and here a material having superplastic properties may be required. In practice, it is often the case that only a part of the blank needs to have superplastic properties, since the remainder of the blank is either not deformed at all during the forming process, or is deformed only to an extent that is within its inherent capabilities. In such cases, it is clearly wasteful to provide a blank which is made wholly of the expensive superplastic material when only a small part is subject to deformation sufficient to need superplastic properties.

[0034] The blank illustrated in Figure 1 meets this requirement by providing that just a part of the blank, namely the insert 3 is made of a material having superplastic properties. The parent body 2 can be of conventional sheet material, although the invention does not preclude the possibility that the parent body also has superplastic properties, but to a lesser extent. Thus, in a

SHP-PT075

particular example, the parent body 2 is made of low-cost conventional aluminium alloy sheet, whereas the insert 3 is made from a more expensive superplastic aluminium alloy. Note, however, that the insert and the parent body do not both have to be of the same material (aluminium in this case); the insert could be a superplastic variety of some other material.

[0035] The insert 3 is made of such a size and shape, and is positioned with respect to the parent body 2, such that it corresponds to that area of the blank 1 which requires superplastic properties. In addition, it will be seen from the above-referred to patent application No. US 2002/0079351 that the use of FSW can itself create or enhance superplastic properties in a material which would otherwise not possess such properties, and it will thus be seen that the area of superplasticity might in fact be extended into the parent body 2 in the immediate vicinity of the weld line during the FSW process.

[0036] The exact shape and location of the insert with respect to the parent body can be determined in various ways. For example computational simulation methods such as non-linear finite modelling may be used to analyse the variation of thickness that will result during the forming process. The contoured thickness and location of the insert necessary to achieve a uniform final thickness after deformation can then be calculated. Alternatively, forming trials may be performed using a biaxial grid marked sheet to determine regions of high strain in the formed part, and the origin of these regions on the unformed flat sheet.

[0037] Figures 2 to 4 illustrate various blanks having differently shaped and/or positioned inserts 3. The blank shown in Figure 2 is the same as that shown in Figure 1, except that the insert 3 has a different shape. The blank shown in Figure 3 has an insert 3 which is completely surrounded by the material of the parent body 2. In this case the route of the FSW tool 4 is as shown, being shown dotted where the route passes through the material of the parent body 2 and in solid where it passes round the joint line itself. Since a complete passage round the joint line returns the FSW tool to the point at which it started, it is most convenient to have the tool leave the blank by the same

SHP-PT075

route as it entered. The blank shown in Figure 4 has two inserts 3.1 and 3.2, each being shaped as required for the particular application. Each insert is joined around its perimeter to the parent body 1 by FSW. In the case of insert 3.1, the FSW tool 4 is plunged into the joint line at some point, then moved around the joint line and back to the same point, at which point the tool is removed and the resultant hole plugged. In the case of insert 3.2, the same technique as is used in the blank of Figure 3 is used to effect welding of the joint.

[0038] Figure 5 shows 3 more blanks suitable for use with the method of the present invention, each of these having differently shaped and positioned inserts. It will be understood that these inserts will be joined to the parent body by FSW; in the case of the embodiment shown in Figure 5B, this will involve two separate welds. The thickness of the or each insert 3 may be the same as or different to that of the parent body 2. This will enable that part of the blank which comprises the insert to have different mechanical properties to the remainder, a feature which may be required in the finished part, or in the forming process itself. In particular, making the insert thicker than the parent body will not only stiffen that part of the blank but also may compensate, wholly or in part, for any thinning which occurs during the forming process. Thus, by selecting an appropriate additional thickness before forming, a near uniform thickness can be achieved in the part after forming, even despite the different strain levels. Alternatively, the insert may be made of sufficient thickness to leave a thickened region in the formed part. Such a thickened region might be required for functional reasons, for example, to give greater strength or stiffness, or to provide for a threaded connection.

[0039] To facilitate FSW of an insert which is of different thickness, it is preferred to bring the thickness of the facing edge along the join line to be the same.

[0040] As well as or instead of making the insert of different thickness than the parent body, the surface of the insert may be contoured to provide a varying thickness across its area. Such contouring may be applied to one or

SHP-PT075

both surfaces of the insert although usually the contoured face will be on the side that does not come into contact with the tool (i.e. it will be on the fluid side). Insofar as such contouring may result in the facing edges of the join line being of different thickness, it is desirable, as before, to bring these facing edges to the same thickness to facilitate the passage of the FSW tool.

[0041] It is envisaged that the blanks shown in Figures 1 to 5 may be used in a forming process utilising a heated mould and fluid pressure to stretch the blank into contact with the mould surface. The position, size and shape of the insert 3 will be such that that part of the blank which comprises the parent body 2 will be brought into contact with that part of the mould whose geometry is such that it requires only a modest strain in the blank (within the capabilities of the parent body) whereas that part of the blank which comprises the insert will be brought into contact with that part of the mould whose geometry requires a higher strain which is not within the capabilities of the material of the parent body (for example because such strain would result in excessive thinning or require protracted forming times) but can be formed successfully from the more expensive superplastic material of the insert. The benefit is thus that the cost of the composite blank (parent body 2 + insert 3) will be less than a blank fabricated wholly from the more expensive superplastic material. Currently many parts formed from superplastic materials have only relatively small local regions, often amounting to less than 10% of the total area of the blank, where significant strain (for example greater than 50%) is needed to create the geometry of the desired part.

[0042] There will now be described, with reference to Figures 6 and 7, a typical sequence of operations in forming a shaped part in accordance with the method of the invention. The part to be formed is illustrated diagrammatically in Figure 7, in which the hatched region 5 containing sharp curves and corners is assumed to be one which, during the forming process, will cause high strain in the material to be used to fabricate the part.

[0043] The first step in the process (Figure 6A) is to select a suitable piece

SHP-PT075

6 of sheet material to form the parent body 2. A piece 7 of material is then cut out of the sheet 6 (Figure 6B) to leave a correspondingly-shaped hole 8 in sheet 6.

[0044] Meanwhile a sheet 9 of a material exhibiting superplastic properties is selected and a piece 10 is cut from this sheet, corresponding in size and shape to the hole 8 in sheet 6 (Figure 6C). It is assumed that the remaining pieces cut out of the sheet 9 will be used to fabricate subsequent blanks. A section 11-11 through piece 10 is represented by the dotted frame 11. As detailed in enlargement 12, the piece 10 may optionally have a contoured surface 16, providing additional thickness at 13, for example to compensate for local thinning, as explained above.

[0045] The piece 10 is now fitted into the hole 8 and welded in place to complete the blank 1 using FSW (Figure 6D). Thus it will be seen that the piece 6 of Figure 6B becomes the parent body 2 of the blank 1, and the piece 10 of Figure 6C becomes the insert 3 of the blank 1.

[0046] The completed blank 1 is now placed over a mould 14 having a cavity 15 shaped to correspond to the part to be formed (Figure 6E). It will be noted that the insert 3 is positioned so as to correspond to the region 5 in the part to be formed. Usually, the blank is clamped around its edges before fluid pressure, as represented by arrows A,B is now applied to stretch the material of the blank into the mould cavity 15 (Figure 6F), thus producing the shape required, as shown in section on the right-hand side of Figure 6F. It will be seen that, during this forming process, part of the parent body is deformed, but not to an extent beyond that of which it is capable. For this purpose, the inherent plasticity of the material of the parent body may be relied upon, or it may be enhanced by treating it to give a level of superplasticity sufficient to enable it to undergo the deformation required of it. It will be seen that a complex part might have several areas of different superplasticity, including some areas which do not exhibit superplasticity at all, these being fabricated with one or more inserts FSW welded into the parent body to provide a potentially quite complex distribution of levels of superplasticity across the blank. It will also be seen that

SHP-PT075

it is possible to provide an insert within an insert to achieve such multiple levels of plasticity. The use of inserts makes such complex arrangements possible.

[0047] Referring now to Figure 8, there are shown a series of views intended to clarify the various ways in which an insert 3 can be fitted to a parent body 2 to fabricate a blank 1 in sheet form. Figure 8A shows the parent body 2 having a prepared hole 20 to receive the insert 3. Figure 8B shows the insert after fitting, and illustrates at 21,22 the weld areas created by FSW. It will be noted that the thickness T of the insert is the same as that of the parent body. Figure 8C shows a view similar to that of Figure 8B, but in which the upper surface of the insert is contoured, as discussed above. Figure 8D shows the joining of an insert 3 in the form of a patch onto the parent body 2 in order to create a layered structure. References 23 and 24 show the FSW welds required to effect joining. Reference 25 shows a further optional weld which may be needed for added strength and/or where the insert is of a larger size. Figure 8E is similar to Figure 8D, but shows an insert in the form of a patch having a contoured upper surface. Figure 8F shows the joining of an insert 3.1 in the form of a patch over an existing insert 3.2 such as illustrated in Figure 8B in order to form a layered insert. Advantageously both parts 3.1 and 3.2 of the layered insert have a similar level of superplasticity so that the performance of one part does not impair the other. References 21 to 24 show the various FSW welds which are used to attach the insert part 3.2 to the parent body (welds 21,22) and to attach the insert part 3.1 to the insert part 3.2 (welds 23,24) although the welds may be arranged differently, as required.

[0048] There now follows some non-limiting examples of combinations of parent body/insert materials that could be used in the present invention. In each case the materials are aluminium alloy sheet identified using their Aluminum Association international alloy designations, that on the left being the parent body, that on the right, the insert:

- (i) Standard AA 5083 to Superplastic AA 5083
- (ii) Standard AA 2024 to Superplastic AA 2004

SHP-PT075

(iii) Standard AA 7075 to Superplastic AA 7475

(iv) Standard AA 6061 to Superplastic AA 2004

[0049] Typical starting gauges might be 1.9 mm (0.075 inches) of standard AA 7075 (for the parent body), and a 4.45 mm (0.175 inches) contoured insert of superplastic AA 7475. In this example, the bulk of the superplastically formed blank has only 50% thickness strain apart from a local area, represented by the insert, where the strain level reaches 250%. This combination of starting gauges would result in a more uniform overall thickness after SPF of about 1.27 mm (i.e. no local "thinness" in the high strain region).

[0050] The insert may be made from exotic materials containing expensive alloying elements such as scandium as described in US 5,055,257 that have greatly improved superplastic properties. Another alternative could be the alloys developed by Grimes et al at Imperial College London produced by rapid cooling of liquid aluminium alloys containing 0.5 to 1.0%Zr as described in the ESPRC Report GR/L43848.

SHP-PT075

CLAIMS

1. A method of preparing a blank for superplastic forming, said method comprising the steps of joining an insert to a parent body by means of friction stir welding, at least one of the parent body and the insert being made of a material which has superplastic properties.
2. A method as claimed in claim 1 wherein friction stir welding is carried out using a tool which is passed along the joint line between the insert and the parent body.
3. A method as claimed in claim 1 wherein the parent body is provided with a cutout into which the insert fits.
4. A method as claimed in claim 3 wherein said cutout opens into an edge of the parent body so that the insert, when joined to the parent body, forms at least part of the external edge of the blank.
5. A method as claimed in claim 3 wherein said cutout is closed, thus forming a hole passing through the parent body.
6. A method as claimed in 1 wherein the insert is placed against the blank and joined thereto so as to form a layered structure.
7. A method as claimed in claim 1 wherein that part of the blank which is made of superplastic material is located so as to correspond to an area of the blank which, during the subsequent forming process, is to be deformed to a greater extent than the remainder of the blank.
8. A method as claimed in claim 7 wherein the insert comprises that part of the blank which is made of superplastic material.
9. A method as claimed in claim 1 wherein the insert is adapted to perform a mechanical function.
10. A method as claimed in claim 1 wherein multiple inserts are joined to the parent body by friction stir welding, and wherein at least one of the inserts and/or the parent body are made of a material which has superplastic properties.

SHP-PT075

11. A method of superplastic forming comprising preparing a blank by the method as claimed in any one of the preceding claims, then forming said blank by pressurising it against a mould.

12. A blank for use in a superplastic forming process in which a limited region or regions of the blank are required to deform to a greater extent than the remainder, said blank comprising a parent body and an insert joined thereto by means of friction stir welding, at least one of the parent body and the insert being made of a material which has superplastic properties, and wherein that part of the blank which has said superplastic properties is positioned so as to correspond to a respective limited region.

13. A blank as claimed in claim 12 wherein at least the parent body is of sheet material.

14. A blank as claimed in claim 13 wherein the insert is the same thickness as the parent body.

15. A blank as claimed in claim 13 wherein the insert is of a different thickness to the parent body.

16. A blank as claimed in claim 15 wherein the insert has a thickness which is greater than that of the parent body.

17. A blank as claimed in claim 13 wherein one or both surfaces of the insert are contoured.

18. A blank as claimed in 15 wherein the thickness of the insert in the region of the join line with the parent body is the same as that of the parent body.

19. A blank as claimed in claim 15 wherein the insert comprises that part of the blank which has superplastic properties.

20. A blank as claimed in claim 19 in which the material of the parent body also has superplastic properties, but to a lesser extent than those of the insert.

21. A blank as claimed in claim 12 wherein the insert comprises means to carry out a mechanical function.

SHP-PT075

22. A blank as claimed in claim 12 comprising multiple inserts joined to said parent body by friction stir welding.
23. A blank as claimed in claim 22 wherein some of said inserts have a different level of superplasticity than the remainder.

SHP-PT075

ABSTRACT

A method of forming and a blank therefor, in which the blank comprises a parent body and an insert, at least one of which is made of a material which possesses superplastic properties. The insert is joined to the parent body by friction stir welding. The primary purpose of the invention is to provide a blank for a forming process during which some parts of the blank are required to deform to an extent which requires superplastic properties, whereas the remaining parts of the blank are deformed to a lesser extent.

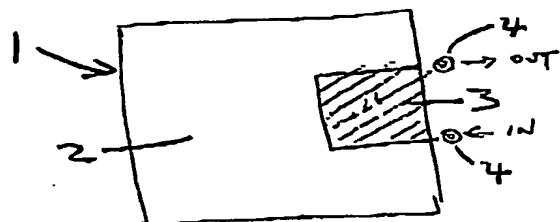


Figure 1

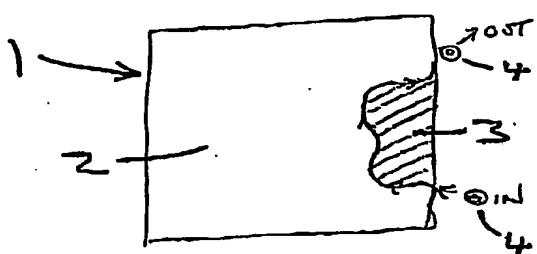


Figure 2

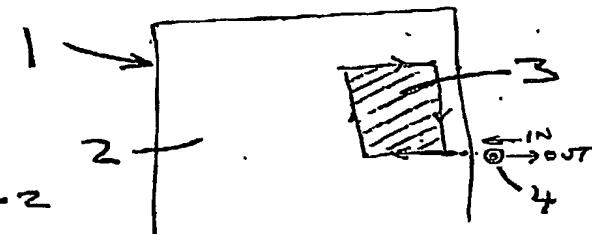


Figure 3

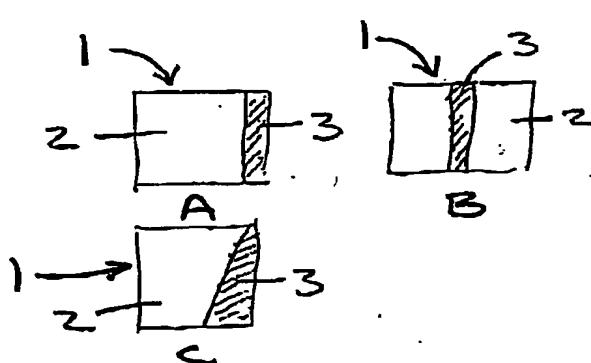


Figure 5

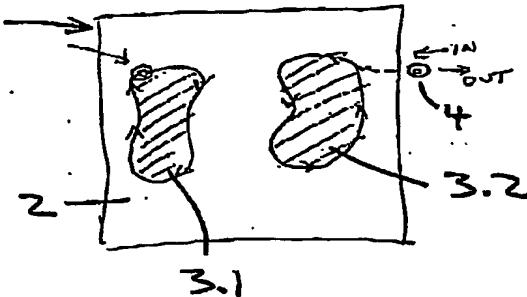


Figure 4

3.1

3.2

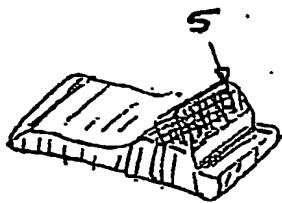
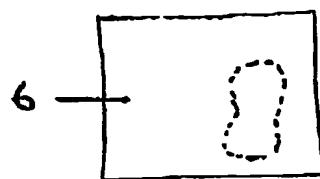
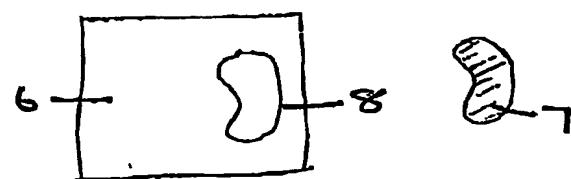


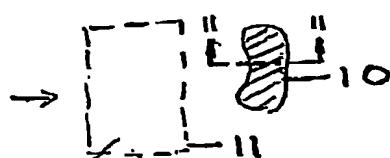
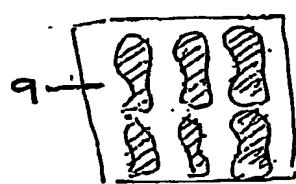
Figure 7



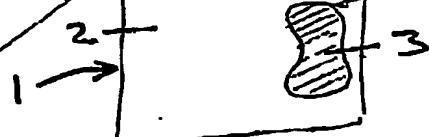
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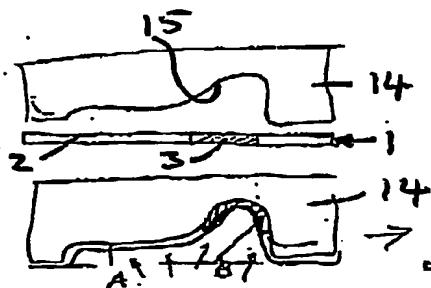
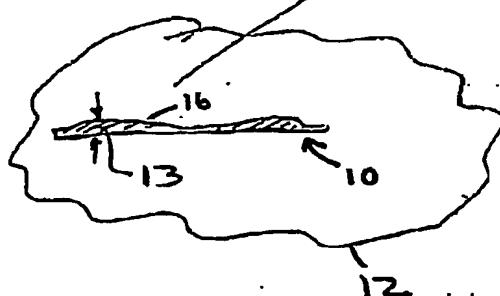
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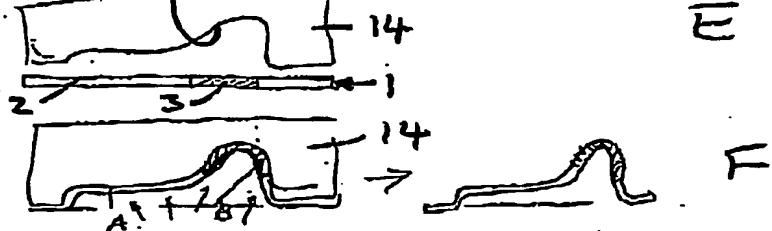


D



E

Figure 6



F

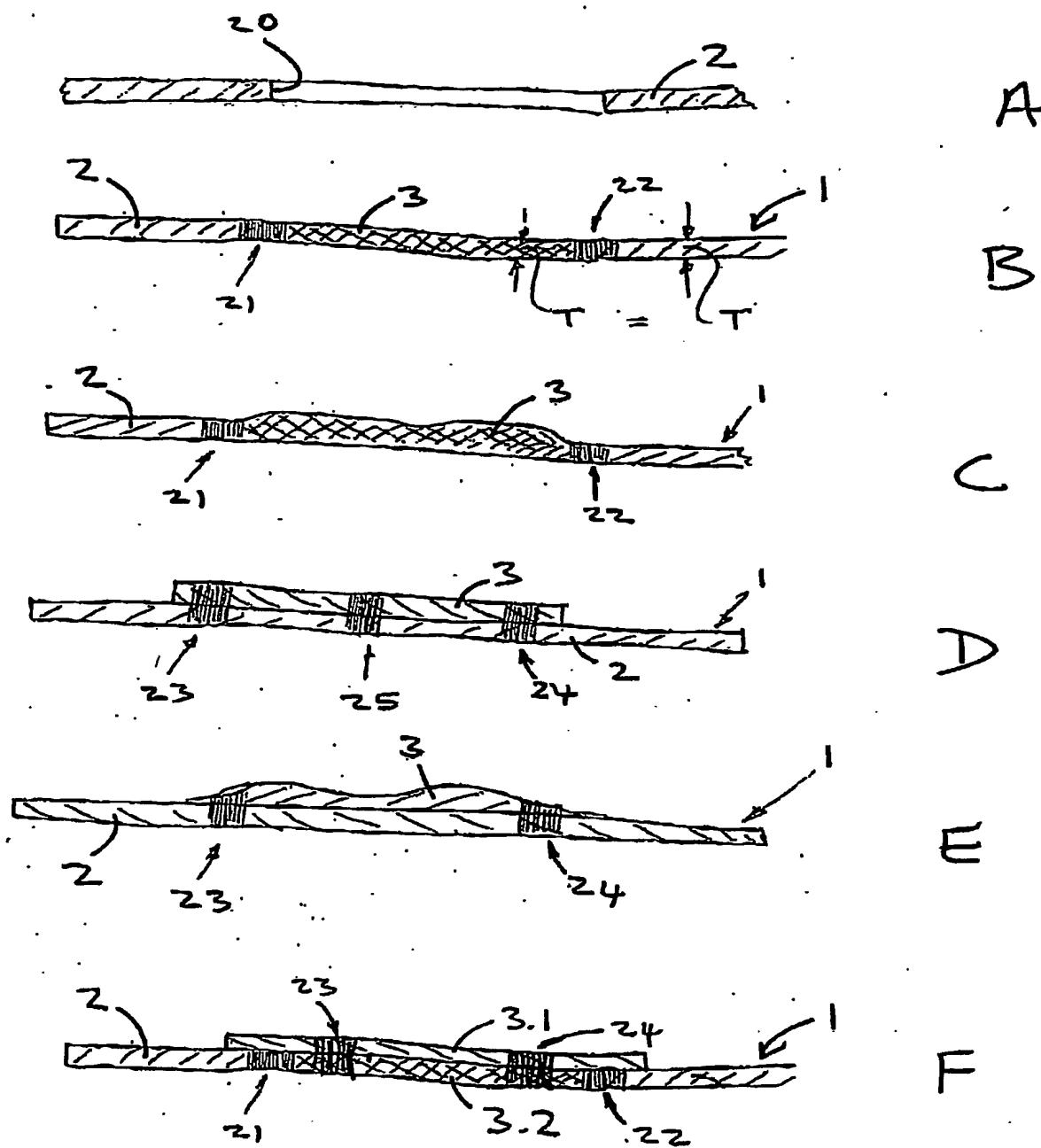


Figure 8